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UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1265

Washington, D. C. ▼ November 22, 1924

SCALDING, PRECOOKING, AND CHILLING AS PRELIMINARY CANNING OPERATIONS

By

C. A. MAGOON, Bacteriologist, and C. W. CULPEPPER, Assistant Physiologist
Office of Horticultural Investigations, Bureau of Plant Industry

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By C. A. Magoon, *Bacteriologist*, and C. W. Culpepper, *Assistant Physiologist*, *Office of Horticultural Investigations, Bureau of Plant Industry.*

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INTRODUCTION.

Experience in the canning of certain food products has indicated that scalding the freshly prepared raw-food materials in boiling water, or exposing them to the action of live steam for a short time, has distinct advantages. This procedure, which is commonly but erroneously termed "blanching," is widely practiced among both home and commercial canners. Commonly associated with it is another operation, namely, the chilling of the freshly scalded materials in cold water before packing into the jars and cans. These two steps in the preliminary treatment were at first applied to a few specific materials, but largely through the influence of enthusiastic proponents of the idea they have come to be applied to the handling of all sorts of materials.

Just what purposes these operations were thought to serve, and the advantages to be derived from them have been set forth in a voluminous literature, the bulk of which has appeared within the last six or seven years. While many of the writers have contributed materially to present-day practices in canning technology, a detailed consideration of their papers is beyond the scope of this bulletin, and a brief general review dealing particularly with the subjects under present discussion will, for the great majority of them, necessarily suffice.

[1] This manuscript was submitted for publication September 7, 1922.

It was Appert (*2*),[2] the man who laid the foundation of modern canning methods, who first practiced scalding in the preparation of certain vegetables for bottling. Asparagus, artichokes, cauliflower, spinach, and chicory were given this preliminary treatment, the object being, as expressed in connection with his discussion on asparagus, "to remove the acridity peculiar to this vegetable." That undesirable substances which have been variously described are eliminated from certain vegetables by scalding has been generally recognized, and because of this, in part, the practice has been widely recommended. The effect of this treatment upon the coloring substances in the various types of materials has received a great deal of attention also. By many, it has been held that the scalding "starts the flow of coloring matter," "intensifies the color," or "brings the coloring matter to the surface," which, it is thought, makes possible a better colored and more attractive product. Others, however, have held that neither the color nor flavor is improved.

That scalding assists in cleansing the material is of course well known, and many writers have asserted the removal of "mucous," "mucilaginous," "gummy," and "viscid" substances from the surface of various fresh raw foods. Shrinkage or reduction in bulk of vegetables and fruits as a result of scalding has been widely noted, and attention has been called to the softening of the tissues and the increase in flexibility of such substances, as string beans, etc. (*1*) which facilitates packing into containers.

Scalding has been found of great value in the peeling of tomatoes and certain other fruits. It has been asserted also that it is of value as an aid to sterilization, and further, that this treatment results in a clearer liquor in the canned product. Other reasons advanced in favor of scalding are, that it makes possible the elimination of the usual "exhaust," that it makes the texture of the canned food firmer, that scalded vegetables cook more rapidly in the can, and that it assists also in the grading of such products as peas, etc.

With a great many writers, chilling the freshly scalded materials by immersion in cold water, popularly known as the "cold dip," is considered a necessary corollary to the scalding treatment, and several benefits claimed to follow the practice of chilling have been noted. Nearly all have recognized the fact that the materials are more easily and comfortably handled as a result of being cooled, and that the pulp of certain fruits, such as tomatoes and peaches, is made firmer, and may thus be more conveniently and economically packed. It appears to be a more or less common notion that in some way the coloring matter in the various fruits and vegetables is "coagulated" or "set" as a result of chilling, so that in the sterilization process which follows the natural coloring substances are not destroyed.

Of particular interest are the statements regarding the value of the combined scalding and chilling operations as aids to sterilization. These, while expressed in different ways, may be summarized by the following quotation from one of these publications: "The change from hot to cold, and vice versa, produces the double shock necessary to successful destruction of spore-producing bacteria."

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[2] Serial numbers (italic) in parentheses refer to "Literature cited" at the end of this bulletin.

Careful perusal of this literature [3] affecting these widely recommended practices shows in many instances lack of knowledge as to what actually does happen when the recommendations are followed, and much confusion has resulted among those who were desirous of knowing what methods to pursue. Furthermore, carefully controlled investigations by scientists of recognized standing, particularly along the line of the losses in nutrients resulting from scalding and cooking in water, and also with respect to the recommended methods as related to the necessary sterilization of canned food, have raised doubts in the minds of many as to the advisability of the unrestricted scalding and chilling operations in the canning of foods.

The wise utilization of our food resources is of fundamental importance. The economical production of our canned foods, the conservation of their nutritive properties, and the maintenance of high quality, and assurance of healthfulness, are matters of vital importance. The operations involved in their manufacture, therefore, should be subjected to critical study, and the principles involved should be thoroughly understood.

This bulletin sets forth the results of studies carried on during the four years ended in the winter of 1921–22, which were undertaken for the purpose of throwing light upon some of these matters, and they are presented here with the hope that they may help in clearing away confusion and assist in the improvement and standardization of canning methods.

APPARATUS AND METHODS USED.

The scalding vessel employed in these studies consisted of an enamel-lined 10-gallon tank fitted with a block-tin steam coil. Its volume was therefore sufficiently great to allow the introduction of suitably large quantities of the test material without checking the vigorous boiling for more than a few seconds. For some of the work, a wire basket, specially constructed to fit the dimensions of the tank, was used, and in part of the work cheesecloth was substituted for this basket.

A steam chamber suitably fitted with wire trays was used for the studies on steam treatment, and enamel-ware buckets were used for the cold-water treatment of the scalded materials.

The source of heat was the 60-horsepower steam boiler used for general purposes, which furnished abundant steam under pressure for all needs. No tests using small kettles or steamers on the stove or open flame were made.

In those experiments involving the canning of the test material, both the standard packers' tin cans and the glass jars in common household use were employed. Processing, when practiced, was done in a water bath of large capacity heated by a steam coil or in an autoclave, as the case required.

The usual chemical laboratory equipment was used for the analytical work.

In all cases during the experiments, time was counted from the instant the material was plunged into the boiling water; or, where

[3] For the benefit of those who desire to look further into the literature of the subjects under discussion, a list of pertinent nontechnical publications is appended to this bulletin.

live steam was used, from the instant the steam was turned on. Exposure of the material to the scalding medium was practically instantaneous.

The analytical part of the work was carried out as follows: Samples were taken of the materials under study, both before and after scalding in boiling water (or test solution) and after exposure to live steam, and then were subjected to careful quantitative analysis. Analyses were also made of the water (or solution) after the scalding was done, and where chilling in cold water was practiced this water too was examined. The total dry matter lost in the scalding process and in the chilling was determined by the evaporation of aliquot portions of the water, which were brought to dryness over calcium oxide, in a vacuum chamber at 100° C. Sugar, protein, and ash determinations were made of the aliquot portions, according to the methods of the Association of Official Agricultural Chemists (*3*).

The procedure with the raw and with the treated samples was as follows: A convenient quantity was weighed out, care being taken to get representative samples, and 95 per cent ethyl alcohol was added to give an alcohol concentration of 75 to 80 per cent. After partial extraction, this alcohol was filtered off through an extraction thimble, and more 95 per cent alcohol added. This was repeated several times, and finally the residue was transferred to the extraction thimble and the extraction completed in a Soxhlet apparatus. In this way, the greater part of the extraction was completed in the cold, so that the use of the Soxhlet apparatus was required only for the removal of the last traces of soluble material. The sugars were determined from the extract, and the polysaccharides from the alcoholic insoluble portion. Except where otherwise stated, the methods used were those of the Association of Official Agricultural Chemists (*3*).

In addition to the analytical work, studies were also made of the effect of the different methods of preliminary treatment upon the appearance, flavor, and other qualities of the canned product. These matters will be considered in more or less detail in the discussion of experiments upon specific food materials.

The vegetables and fruits used were grown specially for the purpose at the Arlington Experiment Farm, near Rosslyn, Va.

EXPERIMENTS WITH SPECIFIC FOOD MATERIALS.

SPINACH.

In these experiments both the fall-planted and the spring-planted spinach were used.[4] The plants were in a state of vigorous growth just preceding the flowering period. Occasional small embryonic flower clusters were observed. The material was gathered in the field between 9 and 10 a. m. and handled at once, the tests being completed within 2 to 3 hours after bringing the spinach from the field.

The older leaves and older portions of stems were trimmed away as usual, and the fresh, crisp material weighed. Experiments were then made upon this material as follows:

[4] Considerable variation in composition of the material was noted, the sugar and total solids being greater in the fall-planted than in the spring-planted spinach.

Carefully weighed lots were washed thoroughly in cold running water, drained, and weighed again. This showed the increase in weight resulting from the washing process. To obtain a base line for comparison in the determination of the amount of shrinkage resulting from the scalding process, weighed quantities of the spinach without washing or other treatment were packed firmly into No. 2 open-top tin cans and the yield in cans of material noted. These findings were later compared with yields obtained similarly from the material subjected to the various methods of treatment.

Lots weighing 1,700 grams, after thorough washing, were packed tightly into tin cans and glass jars without other preliminary treatment. In the case of the tin cans, hot water was placed in the can, the freshly washed spinach packed in as tightly as possible by displacement of water, and the cans sealed immediately. In the case of the glass jars, a small quantity of water only was added to the jar after the spinach was packed in. The test cans and jars were then processed, part by the intermittent treatment in boiling water for 1 hour on each of 3 successive days, part by boiling continuously for 3 hours or more in the water bath, and another part by the application of steam under pressure at 116° C. for 1 hour in the autoclave. These furnished information upon the quality of the untreated spinach as compared with the scalded material.

Lots weighing 1,700 grams were plunged into 16,000 cubic centimeters of boiling distilled water for 2 minutes, drained, weighed again, placed in cans and jars as before, the yield in cans recorded, the cans sealed, and then processed as before. Samples of the raw material, scalded material, and scalding water were taken and subjected to chemical analysis.

The same procedure was followed with other 1,700-gram lots, except that the scalding period was increased to 4 minutes. These tests made possible an observation of the effect of scalding upon the appearance and quality of the product and a determination of the losses caused by the treatment.

The effect of plunging the freshly scalded spinach into cold water immediately after scalding was determined upon other samples handled as just described by draining for 30 seconds after scalding, chilling in cold water for 30 seconds, draining, and then canning. Here, also, samples for chemical analysis both of the spinach and of the scalding and chilling waters were taken at the various stages of the process. The canned product from these tests was used for comparison with the material from the various other tests.

In addition to the scalding tests using distilled water, other experiments of a similar character were performed using boiling 2 per cent brine, 0.1 per cent sodium bicarbonate, and 1 per cent citric-acid solutions.

Since scalding in live steam, instead of in boiling water, has been quite widely recommended for vegetable greens (see references, p. 8) because of the saving in nutrients lost in the boiling-water treatment, tests were carried out in this work to throw further light upon the merits of this method. The effect of steam upon the physical properties of the spinach, and the table qualities of the product, received special consideration.

The findings of these investigations will be presented in more or less detail in the following discussions.

RELATION OF WASHING AND SCALDING TO THE WEIGHT OF SPINACH.

Washing removes, of course, most of the adhering dirt and is a very necessary part of the preliminary treatment of vegetables for canning. Its effect upon the weight of spinach, and some of the other vegetables, was noted particularly. As is to be expected, there is a marked increase in weight, due in part to the taking up of water by the tissues, but especially to the adherence of water to the surface of the leaves. The increase varies with the nature of the material, viz, its freshness, the fineness or coarseness of the leaves, the amount of petiole and stem tissue present, etc. In these tests, the water held in this way amounted to 40 to 50 per cent of the original weight of the spinach.

During scalding, this increase in weight may largely or entirely disappear, so that the weight after scalding is actually less than that of the original unwashed material. Several factors influence this. In these experiments, with material fresh from the field, there was a loss in weight during scalding amounting to 4 to 9 per cent of the original weight. In other samples purchased on the open market a gain of 7 per cent was noted. The amount of gain or loss is dependent upon the freshness of the material, the amount of soluble substances lost into the scalding water, and the extent of draining and evaporation before filling into the can.

SHRINKAGE OF SPINACH.

When fresh spinach is plunged into boiling water or exposed to live steam the turgidity of the cells is promptly lost and the tissues collapse. A much closer pack is thus made possible. The extent of the shrinkage varies with the age of the spinach, the extent of trimming, the extent of the stirring, and the temperature of the bath or steam. To get the maximum shrinkage, the heat must penetrate to all parts of the mass, which means that piling up or packing together must be avoided.

The extent of the shrinkage in these tests was found to vary from 50 to 60 per cent of the original bulk. Differences between the effect of a 2-minute scalding period and a 4-minute treatment were too small to be significant; and the differences between the hot-water treatment and the exposure to live steam in causing shrinkage were believed too small to be important. All that is necessary to get complete loss of turgidity is to bring the temperature of the tissues to 100° C. If this is accomplished in 1 minute, most of the shrinkage occurs during this minute. The freedom with which heat is allowed to penetrate into the mass seems to be the prime practical consideration. This is of particular importance in home canning, where the steaming must be done in small receptacles and with a limited steam supply. Considerable difference in the rate of shrinkage by steam and by water treatment would be found under these conditions, the slow steaming requiring a considerably longer time to effect the same result.

In these experiments, there was 4 to 8 per cent more shrinkage when the scalding was done in a 2 per cent brine than when dis-

tilled water was used. This was doubtless due partly to the osmotic action of salt upon the tissues, and partly to the high boiling point of the salt solution.

From 6 to 10 per cent more shrinkage was obtained when 0.1 per cent sodium-bicarbonate (common baking soda) solution was used than was obtained with distilled water. This was due, apparently, not so much to the effect of the chemical upon the boiling point of the solution as to the solvent action which it had upon the vegetable tissues. With a 2-minute treatment, considerable disintegration of tissues took place, and this was particularly marked in the 4-minute treatment.

No distinguishable differences were observed when 1 per cent citric acid and distilled water were used.

Spinach which was removed from the scalding bath, and placed at once in cold water for 30 seconds, took up water in amount to make the shrinkage about 10 per cent less than that of the spinach which was not chilled.

LOSSES IN SCALDING SPINACH.

When spinach is placed in boiling water the soluble constituents diffuse out into the water, and if this is thrown away, as is usually the case, there is considerable loss of valuable nutrients. The amount of this loss varies with the age of the spinach, the proportion of stem and petioles removed, the extent of stirring, the temperature of the water, and the duration of the treatment.

In these experiments, 1,700 grams of spinach scalded for 2 minutes in 16,000 cubic centimeters of boiling distilled water lost from 16 to 30 per cent of its total dry matter. Analysis showed this loss to be from the most valuable part of the spinach. In a 2-minute scalding, one-half to two-thirds of the sugar was lost, 5 to 10 per cent of the protein, and 25 to 30 per cent of the mineral constitutents. Scalding for 4 minutes in distilled water resulted in a loss of 60 to 75 per cent of the sugar, 8 to 15 per cent of the protein,[5] and 35 to 45 per cent of the mineral constituents.

The spinach dipped for 30 seconds into cold water, following scalding, lost an additional 1 to 2 per cent of the dry matter.

Experiments to determine the effect of repeated use of the water for scalding purposes upon the losses sustained showed that when the water was used for a second and a third time the losses in total solids into the water decreased, the quantity lost in the third scalding amounting to only 75 to 80 per cent of that lost during the first.

When 2 per cent brine was used, instead of distilled water, the losses were somewhat less, but determination of the exact amount was rendered difficult by the fact that during the treatment some of the salt was taken up by the spinach.

Considerably more was lost when the spinach was scalded in a 0.1 per cent solution of sodium bicarbonate than when distilled water was used. Sodium-bicarbonate solution causes a disintegration of tissues, due to its solvent action upon the protein and particularly upon the pectic substances forming the middle lamellæ of the cells. During a 2-minute scalding process, the loss was more than 25 per

[5] Other series of samples did not show such losses in protein.

cent greater with sodium-bicarbonate solution than with distilled water for the same period; and during a 4-minute scalding, the losses were nearly twice as great with the bicarbonate solution as with the distilled water. Although certain volatile substances passed off when spinach was scalded with live steam, there was practically no loss of nutrient material. When water from the condensed steam drips upon the spinach, considerable nutrient matter is dissolved out and lost.

These findings are, in general, in accord with those of other investigators.[6]

EFFECT OF SCALDING UPON THE COLOR AND APPEARANCE OF SPINACH.

Cans of spinach prepared from portions of the spinach used in the foregoing experiments, when opened for examination to note the effect of the various preliminary treatments upon the color and appearance of the canned product, showed the following:

The spinach canned in tin, without a preliminary scalding, was very unattractive. The proportion of liquid to solids was too great, and the contents of the can had a foamy appearance due to the liberation of air from the tissues during the processing. The product from the untreated spinach contained in glass jars, however, was quite as attractive as the scalded material, but the jars were only about half full.

The canned product prepared from the spinach scalded in water was attractive and satisfactory from the standpoint of appearance. No perceptible difference could be distinguished between the colors of the scalded and the untreated spinach. The different periods of scalding, likewise, made no apparent difference in the color of the canned product.

Scalding in 2 per cent of brine had little, if any, effect upon the difference in appearance of the product, as compared with that scalded in distilled water. The only perceptible difference in the spinach scalded in the 0.1 per cent sodium-bicarbonate solution was the slightly greater maceration of the tissues previously noted.

It was thought that the spinach treated with steam showed a slightly more natural color than that plunged into boiling water, but the difference was very slight.

In all the lots handled in the various ways outlined, the bright-green appearance of the fresh spinach was changed to an olive or brownish green color. When fresh spinach is placed in boiling water or steam for a short time and then removed, it appears much greener. This is due in part to the driving out of air from the tissues, or otherwise making the tissues more transparent, so that the green is less obscured, and in part to physical changes in the condition of the chlorophyll. If the heating is continued for a longer time, the material changes to an olive-green or brownish green color.

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[6] The losses incurred in the cooking of vegetables in water have been the subject of numerous investigations (*6, 16, 17, 24, 25, 27, 32, 35, 40, 41, 43, 46, 48, 50, 51, 52, 53, 54*). These have served to focus attention on similar losses during scalding (which is a partial cooking), and a considerable number of papers (*5, 25, 36, 42, 44, 45, 49, 56*) have appeared during recent years, in which the matter has received careful scientific study. The effect has been to modify the procedure in the treatment of certain vegetables, particularly the leafy varieties, by using live steam instead of boiling water, and many of the more recent writers on canning methods recommend exposure to steam in preference to scalding in water.

Both the physical and the chemical changes undergone by the chlorophyll of green leaves under various treatments have been thoroughly investigated by Willstätter and Stoll (*55*), and the work of these writers throws much light upon the matter of retention or loss of the green color during canning operations. According to these authorities (*55*, p. 61), when the green leaves are heated in water, the chloroplasts become swollen and distorted, or may even burst, and the green color becomes more or less diffused throughout the cell. The spectrum analysis at this time shows only small differences from the pure chlorophyll extracted from the untreated leaves. In the fresh green leaves the chlorophyll is in a colloidal state, but when the temperature is raised by the scalding in hot water the chlorophyll passes into a true solution in the waxes within the cells. In any case, the changes which occur in the chlorophyll during the scalding occur also during the first few minutes of the processing, even in the material which has not been scalded.

Chlorophyll is insoluble in water, and therefore does not leave the cells unless the cell walls are ruptured or destroyed. It is seen, therefore, that scalding does not bring the color to the surface of the green vegetables; and, since cooling merely hardens the cell waxes, plunging the freshly scalded vegetable into cold water does not bring about any changes in the chlorophyll which make it more resistant to chemical transformation by the heat of the subsequent sterilization process. This is in complete accord with the findings of the writers during the numerous experiments of the last four years, in which in no instance has it been possible to tell from the appearance and color of the finished product which material had been chilled in cold water and which had not.

Willstätter and Stoll (*55*) have likewise shown that when chlorophyll is heated in the presence of acids it is changed to phæophytin, a brownish compound. Vegetable tissues and juices are normally acid in reaction; and Masters and Garbutt (*41*), in their studies upon the losses incurred in the cooking of vegetables, noted that the water in which the vegetables were cooked, unless sodium bicarbonate had been added, was acid in reaction at the end of the experiment. As the above-named writers have already pointed out, the presence of these acids with their reaction upon the chlorophyll seems to explain why the material which is bright green at the start becomes less attractive in color at the end of the cooking period. It also explains why the spinach or other vegetable which is bright green when it is put into the can or jar comes out of it at the end of the sterilization period with an olive-green or brownish green color.

Copper salts form with chlorophyll a comparatively stable compound which gives to vegetables a deep-green color when these substances are used in the scalding water. In some European countries copper salts have been quite commonly used to artificially color certain canned vegetables, but owing to the poisonous nature of copper salts, their use for this purpose has been forbidden in this country.

Several investigators (e. g., *41*) have used sodium bicarbonate to preserve the green color of vegetables in cooking. The soda tends to hasten the cooking and to neutralize the acids which cause the decomposition of the chlorophyll. Experiments were performed to determine whether this could not be used to preserve the green color

of the canned spinach. It was found that if sufficient bicarbonate was used to make the material distinctly alkaline, the green color would be preserved to a considerable extent, but that such material was distinctly objectionable to the taste. Unless the spinach was made distinctly alkaline, however, the chlorophyll was destroyed in the processing of the cans, and the product came out with the usual olive-green or brownish green color.

EFFECT OF SCALDING UPON THE TASTE AND FLAVOR OF SPINACH.

In the cooking of fresh vegetables in an open pot or kettle, some of the volatile flavoring substances pass off in the steam. In the case of some vegetables it is desirable to retain these, but with others the retention of the volatile substances results in a less palatable product. This is true of spinach. In these tests, the spinach sealed in the tin cans without any preliminary scalding was decidedly objectionable to the taste, due to the rank and pungent flavors which were prevented from escaping from the can. But spinach packed in glass jars which were not sealed, so as to allow the volatile substances to escape, was pleasing to the taste and satisfactory.

The chemical nature of these volatile substances was not studied in the present work, but it is probable that they were made up in considerable part of essential oils. Masters and Garbutt (*41*) have noted the liberation of hydrogen sulphid during the cooking of green vegetables, and Ott (*45*) has also noted the liberation of sulphur compounds, but it would seem that in the brief cooking which takes place during the scalding the amount of sulphur compounds given off would be very small.

The spinach scalded in steam was judged to be somewhat better flavored than that scalded in boiling water, and it was sweeter to the taste. This showed again for the steam-treated material that the substances objectionably affecting the taste were readily volatilized and passed off in the steam and that the sugar, which is in large measure lost when the spinach is scalded in water, was retained in the steamed material.

The spinach scalded in 2 per cent brine was considered as having a better flavor than that scalded in distilled water, but when the latter was seasoned with salt in equal quantity no marked differences in flavor were detected.

In the case of spinach chilled in cold water after scalding, and that of spinach not chilled, there were no distinguishable differences in flavor.

CHEMICAL CHANGES IN SPINACH DURING SCALDING.

The spinach used in these analyses was from seed planted in the spring, and was found to be somewhat lower in total solids than that from seed planted in the fall.

Table 1 shows the results of chemical analyses of the material, both before and after the scalding process, and also after chilling in cold water following the scalding process. The analyses are not complete in all respects, but they show in a general way the nature of the changes which occur when spinach is being prepared for the can. Analyses of numerous series of similar samples would have been desirable, but lack of time and material prevented a thorough chemical study. The losses which occurred are not evident from this

table, as it merely shows the percentage composition of the spinach before and after the scalding and chilling treatments.

TABLE 1.—*Results of chemical analyses of spinach, before and after treatment.*

[Each result is the average of three samples.]

Treatment of material, if any.	Average constituents (per cent).						
	Moisture.	Solids.	Alcohol.		Sugar, as dextrose.	Polysaccharides, as starch.	Nitrogen, as protein.
			Soluble.	Insoluble.			
Untreated	91.61	8.39	2.75	5.63	0.18	0.76	2.39
Scalded 2 minutes in boiling water	92.31	7.69	2.08	5.60	.10	.73	2.76
Scalded 2 minutes, drained 30 seconds, and chilled in cold water 30 seconds	92.72	7.28	1.54	5.73	.09	.70	2.77
Scalded 4 minutes in boiling water	92.59	7.41	2.06	5.32	.09	.71	2.58
Scalded 4 minutes, drained 30 seconds, and chilled in cold water	93.11	6.89	1.65	5.23	.05	.66	2.56

Extended discussion of the figures appears unnecessary. It is seen that spinach has a high moisture content, is relatively high in protein content, and low in carbohydrates. In this case, the percentage of moisture is slightly greater in the scalded than in the unscalded spinach, though this may vary, as already pointed out. The chemical changes that occur in the chlorophyll have been discussed under the topic of color and appearance. The percentage of total protein is not very different in the scalded and the unscalded material.

A detailed study of the changes that occur in the protein was not undertaken. Any albumins present would be coagulated, and other proteins would probably be altered. Certain sulphur-containing proteins are altered with more or less elimination of hydrogen sulphid. The polysaccharides seem to be a mixture in which the quantity of starch is very small. In this case, no blue color developed upon the addition of iodin. Starch, if present, would be gelatinized in scalding.

One significant change noted in this study was the effect of scalding and the subsequent processing upon the pectinlike substances which hold the cells together. The middle lamellæ swell and often dissolve, so that the cells become more or less separated from each other or may be separated from each other by the mechanical treatment received in subsequent handling. This was especially noticeable in the fibrous portions of the material. Sodium bicarbonate in the scalding water hastens this action and increases the disintegration of tissues. It is because of this action that soda shortens the time necessary to cook spinach and some other vegetable foods.

CONCLUSIONS REGARDING THE SCALDING OF SPINACH.

These studies have indicated that some form of precooking is advantageous in the canning of spinach. Driving out the air from the tissues reduces the bulk, and facilitates the packing; it likewise reduces the internal pressure of cans during processing, which otherwise would be excessive. If filled into the cans hot it also lessens

the time required for the heat to penetrate to the center of the can and thus shortens the length of the processing period. It also eliminates certain volatile constituents which are objectionable to the taste. However, when packing in glass, the flavor of the scalded material does not differ essentially from the unscalded, and consequently the principal advantage in this case is that a full pack may be obtained. Scalding does not make the coloring substances more stable chemically or any less subject to decomposition in the subsequent processing.

Exposure to steam is preferable to scalding in water, other conditions being the same, as the steamed product is better flavored and more nutritious.

These studies have indicated that not only is there no advantage in plunging the freshly scalded spinach into cold water, but that this is an expensive and wasteful practice.

PEAS.

The preliminary treatment of peas in preparation for canning is a subject worthy of careful study. The rapidity with which peas undergo transformations after harvesting and shelling which render them less desirable as food, has always been a serious problem to the canner. Modern harvesting and vining machinery and other mechanical devices have reduced to a practical minimum the period between the gathering of the peas and the canning operation, but the commercial canner is still handicapped by the fact that the peas are of different stages of maturity as they come from the viner and are all more or less contaminated with dust and the juices of the vines. Occasionally, also, the work is delayed so that the freshness of the peas is lost. On the other hand, the housewife who goes out to the garden and gathers the peas which are to be used immediately avoids some of these difficulties. She is able to select the peas when they are all in prime condition for canning, shelling by hand prevents the contamination from dust and vine juices, and prompt handling makes it possible to avoid the deterioration of flavor.

Scalding the peas during the preliminary operation is practiced probably by all the commercial packers in this country, and many home canners consider it a necessary step in the preparation of the peas. Whether it is a necessary or desirable procedure in all cases is considered a doubtful matter by many.

Feeling that the matter needed investigation, the following experiments were carried out:

The peas were gathered by hand in the morning fresh from the field and, except in those instances noted later, were all in prime table condition. The variety was Early Alaska. Shelling was by hand and the tests were performed immediately, so that only a few hours elapsed between picking from the vines and placing the peas in the cans. Except in special cases, the peas were not graded.

Determinations of the amount of shrinkage; of losses in nutrients; of the effect of scalding with steam, boiling water, and solutions of various chemicals upon color, texture, and flavor; of the relation of maturity to the quality of the product; of the effect of holding the shelled peas over night before canning; of the relation of scalding to clarity of the liquor; of the effect of chilling in cold water follow-

ing the scalding process; and of various other factors concerned in the preliminary treatment of peas were made upon this raw material. The results will be discussed briefly in turn.

RELATION OF WASHING AND SCALDING TO THE WEIGHT OF PEAS.

Freshly shelled peas, after washing and draining, showed an increase in weight of about 6 per cent. After scalding for 4 minutes and draining for 3 minutes, these peas lost 3 to 4 per cent of their original weight; and when they were chilled in cold water for 30 seconds after scalding, they showed an increase of about 7 per cent over their original weight.

SHRINKAGE OF PEAS.

The amount of shrinkage in peas varies with the degree of maturity, the young tender peas showing more and the mature ones much less reduction in bulk. The quantity of peas available was not sufficient to determine shrinkage in the various grades, and the figures obtained were on mixed peas. Most of them were full but not hard; that is, in prime condition for the table. The loss in bulk as a result of scalding was determined by measuring into No. 2 tin cans, both before and after the scalding treatment.

Lots aggregating approximately 20 kilograms in weight after being scalded 4 minutes in boiling water, showed a loss in bulk of from 10 to 14 per cent. Peas of the same picking when scalded for 8 minutes in boiling water lost approximately 15 per cent of their bulk, showing that the greatest amount of shrinkage takes place in the first 4 minutes of treatment. When heated with steam for 4 minutes, peas of the same age and kind showed a loss in bulk of 6 to 9 per cent.

When placed in cold water for a short time after scalding, these peas regained their original volume. This taking up of water is of practical importance, and especially when canning in tin, because overfilling, with the undesirable attendant conditions of cloudy liquor and the swelling of cans, may easily result unless great care is exercised. With older peas, the taking up of water was greater, and resulted in an actual increase over the original volume of the peas.

Bitting (*9*) has noted an actual increase in size in peas following a 10-minute scalding. According to this writer, 28 per cent of even the "petit pois" of grade 1 showed an increase in size, and 82 per cent of grade 3. The results were due doubtless to the swelling of starch in the peas, as the increase was less marked when the scalding period was shorter.

Chilling in cold water, therefore, does not cause further shrinkage, as is sometimes stated in the literature, at least in the case of peas.

LOSSES IN SCALDING PEAS.

The losses resulting when peas are scalded varies with the age of the peas, proportion of peas to scalding liquor, vigorousness of boiling, and length of the scalding period. Where chemicals are used in the water, these may also have an influence upon the amount of substances lost. In the present experiments, the losses of the various constituents were considerable.

When 1,700 grams of peas were scalded in 16 liters of boiling distilled water for 2 minutes, there was a loss of 8.2 per cent of the total solid matter; and 11.6 per cent when scalded for 4 minutes. When scalded and then put into cold water for 30 seconds there was an additional loss of 0.24 per cent.

When peas were scalded for 4 minutes in boiling water, sugar amounting to 1.28 per cent of the fresh green weight of peas, or 30 per cent of the total, was extracted by the water. The figures for the 2-minute scalding period are lacking, due to the accidental discarding of the water before a test for sugar had been made.

During a 2-minute scalding 4.3 per cent of the protein was lost into the scalding water, and 17.5 per cent was lost when the scalding period was prolonged to 4 minutes.

The losses in mineral constituents were 24.1 and 34.3 per cent for the 2-minute and the 4-minute periods, respectively; and 1 to 1.4 per cent more was lost when the peas were plunged into cold water for 30 seconds, following scalding.

EFFECT OF SCALDING UPON THE COLOR AND APPEARANCE OF PEAS.

The effect of heat and acids upon chlorophyll has already been considered in the discussion of the work of Willstätter and Stoll (*55*) in connection with the studies on spinach, and what was said there relative to the loss of the green color of spinach applies equally here in the consideration of the green color of peas. When peas are removed from the scalding bath they are bright green, due to the expulsion of air, the taking up of water, etc., but this greening is not permanent. As in the case of spinach, the peas turn to an olive-green or brownish green color during processing. The practice of using copper salts in connection with the canning of peas, as is done in some of the European countries, is due to this fact, as was earlier pointed out.

As in the case of spinach, peas were canned both without preliminary scalding and with treatment with live steam, with boiling water, and with various chemical solutions. The resulting products were then subjected to critical examinations to determine the effects on the appearance and quality of the peas. Comparisons of the canned product from peas receiving no preliminary treatment with that from peas which had been scalded in boiling water revealed no significant differences in color or appearance when perfectly fresh peas had been used. The same was true for peas scalded in 2 per cent brine, 0.1 per cent sodium carbonate, and 1 per cent citric acid. In all cases the color was the usual olive green.

Since experiments with spinach using solutions of sodium bicarbonate had indicated that some alkaline substances might be used, perhaps, to preserve the green color of some vegetables, similar but more extended trials were made with peas. It was found that when either sodium bicarbonate or sodium carbonate was used in sufficient quantities the green color could be preserved largely, but the peas were made too soft to retain an attractive appearance, many of them were burst open, and the flavor was so seriously impaired as to make them distinctly objectionable.

Treatment of the peas with a 0.5 per cent solution of ammonia following a 2-minute scalding yielded peas having a fresh green

color, but they were too soft, and the flavor and odor were objectionable.

Limewater, when strong enough to make the peas slightly alkaline, preserved the green color to some extent, but it gave an undesirable flavor and rendered the peas practically inedible.

Chilling the freshly scalded peas in cold water had no effect upon the color or appearance of the canned product.

EFFECT OF SCALDING UPON THE TASTE AND FLAVOR OF PEAS.

Personal preferences differ considerably as regards the preparation of green peas for the table. To some, the liquid in which peas are cooked is particularly appetizing and, as has been shown in the discussion of losses, where too much water has not been used this liquid is fairly rich in food value. Others prefer to drain away the liquid and substitute cream, milk, or other ingredients. The same holds for peas canned without preliminary scalding, and those that have been scalded. Peas canned in tin without precooking were found to have a richer fresh-pea flavor than those that had been scalded, but it is probable that while the untreated peas might be more pleasing to many consumers they would not be appreciated by others.

Peas treated with live steam were sweeter in flavor than those scalded in boiling water, due to the retention of the sugars, but there was no difference in the sweetness of the peas scalded in steam and those receiving no scalding treatment.

There were but slight differences in flavor between the untreated and the scalded peas when glass jars were used, since most of the volatile flavoring matters escaped during processing in both cases, but the untreated peas were judged to have slightly more of the fresh green-pea flavor.

The effect of plunging the scalded peas into cold water was to detract somewhat more from the flavor, though the differences between the peas that were chilled and those that were not were too small to be particularly noticeable.

From the standpoint of flavor scalding in brine had no advantage over scalding in plain water when salt was used in the liquor. The value of the salt was merely that of a seasoning agent. The alkaline substances, as already noted, when used in sufficient quantities to affect favorably the color of the product, seriously impaired the flavor. One per cent citric acid likewise offered no advantage and detracted from the flavor.

EFFECT OF SCALDING ON THE SOFTNESS OF THE PEAS.

In several publications Bitting, (*10*, *11*, *12*) has stated that peas which do not receive sufficient treatment in the preliminary scalding remain hard in the can, even after processing. The writers, however, have been unable to verify this in their experiments. Differences in the softness of peas between those canned after a preliminary scalding and those from the same lot not precooked at all, were so slight as to be insignificant.

These investigations indicate that the softness of the canned product depends not upon the scalding but upon the degree of maturity

of the peas, the character of the water used, and the length of the processing period. Under the conditions of these experiments, peas suitable for canning purposes always yielded an agreeably soft canned product except in those cases where lime or other chemicals were used. Careful scalding will not make peas of mixed grades equally tender. Hard peas will require longer cooking than young, tender ones, whether cooking is done in the scalding process or after putting into the can, and a precook timed to render the hard peas tender will overcook the younger peas with which they are mixed. Accomplishing uniformity in the canned product, as far as softness is concerned, depends upon the efficiency of the grader and processor rather than upon the scalder.

The fact that the softness or hardness of the water used in the packing of peas and other vegetables has a very important bearing upon the tenderness of the product is quite well known, and Huenink and Bartow (*33*) have made this a matter of careful study. According to these workers, the presence of the chlorides and sulphates of calcium and magnesium is especially important in causing the hardening of canned foods. Hardening due to the use of lime salts in some of these experiments has already been mentioned.

The reason for the hardening of the peas and other vegetables in hard water seems to be the union of calcium and magnesium with the pectic substances of the middle lamellæ, forming relatively insoluble calcium and magnesium pectates. The other alkaline earth metals act similarly. The use of sodium carbonate and the carbonates and hydroxides of the other alkali metals causes a softening, due largely to their action upon these pectinlike materials.

MUCILAGINOUS SUBSTANCES ON PEAS.

Numerous writers (see reference, p. 43) have called attention to the presence of mucilaginous, mucous, sticky, or gummy substances on the surface of certain vegetables, especially peas, and have considered scalding necessary to remove this objectionable material. Many years of familiarity with green peas, in the field, the kitchen, and the laboratory, make it difficult for the writers to understand how such properties should have been ascribed to fresh green peas. There is scarcely anything that grows in the garden that is more nearly free from mucilaginous or sticky substances than fresh green peas. Microscopic examination shows that the outer portion of the pea has a highly cuticularized surface, which is chemically the most insoluble portion of it. When the peas are shelled by vining machines, which are used in modern commercial canneries, the peas may be more or less sticky as they come from the machine, due to the coating with juices from the vines and pods. If allowed to stand for some time in large quantities, natural respiratory processes cause a rise in temperature, and the bacteria, which are present in the juice as a result of the introduction of dust during the vining process, begin to develop. Through the action of these bacteria, the sticky or slimy condition may become such as to greatly impair the quality of the peas for canning purposes.

In home canning, on the other hand, sliminess is never encountered unless the peas have been allowed to stand in considerable quantity for some time. Sliminess here indicates that bacterial action is well under way, and that slack methods of handling have been followed.

In any case, sliminess due to bacterial action should be carefully avoided, and thorough cleansing and prompt handling will obviate any difficulty in this respect.

It is held by many canners that scalding in boiling water is the only way to thoroughly cleanse peas for canning, but further study may alter this view.

CLARITY OF THE LIQUOR IN CANNING PEAS.

In the literature, one of the reasons given for scalding is that the liquor in the scalded product is freer from cloudiness than in the untreated. With fresh green peas, this was not found to be the case, for the liquor in the untreated peas was as free from sediment and cloudiness as it was in the case of the scalded peas. Determinations of the total solids in the liquor, both when the peas were not scalded and when they were scalded (for 4 minutes), showed a slightly higher percentage of solids in the former, but this was due to the going into solutions of sugars and other nutrient substances and not to suspended material.

A large quantity of unshelled peas which were held overnight in a warm room, and which by morning had begun to heat somewhat, yielded a product the liquor of which was turbid and unattractive when the peas were not scalded. Peas of this same lot which were given a preliminary scalding showed a somewhat clearer liquor. Like results were noted with a large quantity of shelled peas that were held overnight in a large basket in a warm room.

Cloudiness was also observed in the liquor of peas that were allowed to stand in water for some hours before canning.

In one experiment, in which some peas from a given lot were canned fresh and others canned at intervals of 24 hours over a period of three days, there was a progressive increase in the turbidity of the liquor of the peas held for these intervals, the liquid becoming so thick in the oldest samples that it could scarcely be poured from the can. Scalding in water improved the condition somewhat in the younger samples, but this did not overcome the difficulty entirely. In the older samples scalding seemed to be of no particular value.

In another experiment, peas were allowed to remain on the vines in the field until they were fully mature but not yet beginning to dry. These peas were, of course, low in sugar and poor in flavor. The liquor of these peas when canned was heavy, and in some cases too thick to pour from the can. This was probably due in part to the fact that with peas in this condition it was difficult to determine the proper fill, and the swelling which took place caused bursting of some of the peas. No particular advantage resulted from scalding peas at this age so far as clarity of liquor was concerned.

Where thorough washing has not been done, scalding in boiling water helps to clean the peas, and a clearer liquor may be obtained; but with fresh material shelled by hand no difficulty was experienced by the writers in getting satisfactory clarity of liquor with no scalding.

RELATION OF SCALDING PEAS TO PRESSURE AND VACUUM.

In a previous publication the writers (*38*) called attention to the great internal pressure developed in cans of peas during processing

when the peas were canned without any preliminary scalding, whereas in cans of peas which were given preliminary scalding the strain on cans was much less. At the same time, it was pointed out that when scalding was not practiced, the vacuum was also unfavorably affected.

Expulsion of the gases from the tissues is likewise necessary for the preparation of an attractive-appearing product, and to make possible a satisfactory fill.

CHEMICAL CHANGES RESULTING FROM SCALDING PEAS.

Table 2 shows the results of chemical analyses of peas sampled, both before and after scalding, for different periods and also after chilling for 30 seconds in cold water. No analyses were made of the material treated with steam.

TABLE 2.—*Results of analyses of Early Alaska peas before and after treatment.*

[Each result is the average of three samples.]

Treatment of material, if any.	Average constituents (per cent).							
	Moisture.	Solids.	Alcohol.		Sugars.		Polysaccharides, as starch.	Nitrogen, as protein.
			Soluble.	Insoluble.	Total, as invert.	Reducing.		
Untreated	77.04	22.96	7.99	14.97	3.95	0	8.27	3.45
Scalded 2 minutes in boiling water	77.47	22.53	6.93	15.60	3.48	0	8.03	4.33
Scalded 2 minutes in boiling water and chilled 30 seconds in cold water	80.46	19.54	6.12	13.42	2.98	0	7.05	4.46
Scalded 4 minutes in boiling water	78.75	21.25	6.42	14.83	3.01	0	8.00	5.11
Scalded 4 minutes in boiling water and chilled 30 seconds in cold water	81.69	18.31	5.06	13.25	2.67	0	7.08	4.48

These analyses were of 100-gram samples of the raw and the treated peas. The figures show the influence of scalding and chilling in cold water on the chemical composition, but the extent of the losses is not apparent from these figures.

Peas are rich in protein and digestible carbohydrates—mainly starch and sugar. The sugar seems to be almost entirely cane sugar.

The differences in the chemical composition observed between the fresh green peas and the treated product appear to be due not so much to chemical transformations brought about in the brief heating as to losses resulting from mechanical injury; to the solvent action of the scalding water upon the sugars, mineral matter, and pectic substances of the middle lamellæ; and to losses resulting from the bursting of peas through swelling.

Scalding yields a product of higher moisture content than the fresh peas, and of lower sugar and total polysaccharide content. The sugar seems not to be inverted during the scalding treatment, and there is no appreciable conversion of the starch to sugar.

The transformations occurring in the proteins can not be determined from the total nitrogen content, but any albumin, if present, would have been coagulated. The extent of hydrolysis occurring in the protein was not determined and is not known.

Microchemical examination of the raw and the scalded peas showed that the middle lamellæ were softened or partly dissolved during the

scalding. Certain important changes occur in the pectic substances, which have much to do with the softening of the peas.

CONCLUSIONS REGARDING THE SCALDING OF PEAS.

From a consideration of the foregoing experimental findings, it appears that some form of preliminary scalding is desirable in the canning of peas. Scalding is necessary when the canning is to be done in tin, because of the strain on the cans from internal pressure and the low vacuum obtained with material not scalded; but it is not essential in home canning in glass.

Scalding in water results in considerable loss of valuable nutrients from the peas into the scalding water. Treatment with live steam effects the desired shrinkage, makes possible the retention of the sugars and other water-soluble constituents, and yields a satisfactory product. Scalding in water is of value for cleansing purposes, but should not be practiced if it can be avoided.

Scalding appears to be of no particular value for bringing about softness in the finished product. Scalding with hard water may actually make the peas harder, because of the formation of relatively insoluble compounds of the pectic substances with the alkaline earths.

Mucilaginous or sticky substances are not normally present upon fresh green peas.

Scalding does not result in a better colored canned product, and does not produce a clearer liquor when fresh green peas are used.

The effect of scalding on taste and flavor is desirable or not, according to the personal preferences of the consumer. Scalded peas canned in tin have less flavor than those which are untreated, but the differences are not important in glass.

STRING BEANS.

The experiments with string beans were made with two varieties—Stringless Green Pod and Refugee Wax. The former is a plump-podded variety, green in color, and one of the best for canning; Refugee Wax is one of the best yellow-podded varieties. They were selected as representatives of the two types of string beans usually canned.

The beans were gathered fresh from the field early in the morning and handled as rapidly as could be done. They were in prime table condition, the pods well grown, crisp, and tender. After snipping the ends of the pods, they were broken in 1 to 1½ inch pieces and used at once.

The various experiments with beans were conducted the same as with peas and spinach. The results are discussed briefly as follows:

EFFECT OF WASHING AND SCALDING ON THE WEIGHT OF STRING BEANS.

Beans, in lots aggregating 560 kilograms in weight, when washed, drained, and weighed again showed an increase in weight of 6.5 per cent, due principally to the adherence of water.

When fresh, unwashed beans were weighed, both before and after scalding in water, there was an average loss of about 2 per cent in weight. The water adhering after washing was lost during the scalding treatment. A slightly smaller loss in weight was noted

when the beans were scalded for 8 minutes than when the scalding was for 4 minutes, but it was too small to be significant. The loss in weight during treatment with steam was slightly more than with boiling water, averaging about 3.3 per cent of the original weight. Samples of beans purchased on the market weighed more after washing and scalding. Therefore, there may be an increase or a decrease in the moisture content during scalding, depending on the condition of the material and the method of handling.

SHRINKAGE OF STRING BEANS.

The physical character of the string beans when prepared for canning is such that a satisfactory pack is impossible unless some means is employed to reduce the turgidity of the tissues. Scalding, either with steam or boiling water, does this.

In the experiments to determine the amount of shrinkage when beans were given a preliminary scalding, it was found that in a 4-minute treatment in boiling water there was a reduction in bulk of 17 to 25 per cent, and of 22 to 29 per cent when scalded for 8 minutes; that is to say, the beans required that much less space in the cans after scalding than before. Treatment with live steam for the same periods gave approximately the same figures. The reduction in bulk was about the same with both the Stringless Green Pod and the Refugee Wax varieties.

LOSSES IN SCALDING STRING BEANS.

In scalding string beans, the factors which influence the amount of loss of the various constituents are the same as with peas and spinach. The total losses, however, are considerably less. The pentosans and closely allied substances in string beans are relatively insoluble, which explains why the tissues are less readily softened and losses resulting from scalding are relatively small.

When 1,700 grams of freshly prepared string beans were scalded for four minutes in 16,000 cubic centimeters of boiling distilled water, 1.24 per cent of the total solids and 11.4 per cent of the mineral constituents were lost in the scalding water. When scalded for eight minutes, 10.39 per cent of the total solids and 20.75 per cent of the mineral constituents[7] came out into the scalding water.

During a four-minute scalding 5.88 per cent of the total nitrogen was lost.

EFFECT OF SCALDING UPON THE COLOR AND APPEARANCE OF STRING BEANS.

As with spinach and peas, no differences in color were noticed in the finished product when the beans had been scalded and when they had not been precooked. In all cases with the green-podded variety, the color of the product when the cans and jars were opened was olive-green or brownish green, regardless of the temperature and period of the process. Where the temperature was higher and the time periods longer, the canned product was darker, due to overcooking. When the yellow-podded wax beans were used, the finished product showed no significant differences in color, aside from the darkening due to severe processing, as already mentioned. The wax

[7] The increased losses from plunging the scalded beans into cold water were too small to be of importance, and the figures are omitted.

beans are characterized by lack of chlorophyll, the coloring substances present being carotinoids. These results indicate that the color of canned string beans is not improved by scalding.

As with peas and spinach, scalded green beans are bright and attractive in color when removed from the scalding bath, for the same cause explained in connection with spinach. Action of the plant acids on the chlorophyll during processing causes chemical change of the chlorophyll to phæophytin, the brownish green compound previously discussed.

Chilling the freshly scalded string beans in cold water had no effect upon the retention of the color in either the green-podded or the yellow-podded varieties so far as could be determined. Repeated tests during the four years of study were made on this point, and in every case persons invited to select jars of beans which they thought had superior color just as often selected unchilled beans as those that had been chilled.

For the reason that turgidity of the fresh beans makes it impossible to get a good pack unless they are made flexible by scalding, those cans and jars of beans which were not scalded were slack filled, and, in this respect, less attractive than those that had been scalded.

EFFECT OF SCALDING ON THE TASTE AND FLAVOR OF STRING BEANS.

Examination of the canned product from both the scalded and the untreated beans showed but little difference in flavor. This was especially true of the beans packed in glass, the partial seal allowing the objectionable volatile substances to escape with the steam. Even in tin the differences were small.

Beans scalded in water and those scalded in live steam were equally good in flavor.

Chilling in water after scalding had little, if any, effect on the quality of the canned beans.

MUCILAGINOUS SUBSTANCES AND CLARITY OF LIQUOR IN CANNING STRING BEANS.

No mucilaginous or sticky substances were found on the beans, and the clarity of liquor was satisfactory in all cases, therefore scalding in connection with both of these matters seems unnecessary.

RELATION OF SCALDING STRING BEANS TO PRESSURE AND VACUUM.

In a bulletin by the writers (*38*), previously referred to, attention was called to the internal pressures developed in cans when the beans were not scalded. It is essential that the air be expelled from the fresh tissues, not only to get a better pack, but also to reduce the strain on cans during processing, and to attain a higher vacuum. What has just been said relative to internal pressure applies to canning in tin. In packing in glass, this factor is not important because the gases are allowed to escape before the jars are sealed.

CHEMICAL CHANGES RESULTING FROM SCALDING STRING BEANS.

In Table 3 are shown the results of careful chemical analyses of fresh green beans and of beans given both steam and boiling-water treatment. The effect of chilling in cold water after scalding is shown also.

TABLE 3.—*Analyses of Stringless Green Pod string beans, before and after treatment.*

[Each result is the average of three samples.]

Treatment of material, if any.	Average constituents (per cent).									
	Moisture.	Solids.	Alcohol.		Sugars.			Polysaccharides, as starch.	Pentosans.	Nitrogen, as protein.
			Soluble.	Insoluble.	Reducing.	Nonreducing.	Total.			
No treatment	89.40	10.60	4.46	6.14	2.34	0	2.34	2.60	1.15	1.72
Treated 4 minutes with live steam	89.60	10.40	4.38	6.02	2.39	0	2.39	2.58	-------	1.71
Treated 8 minutes with live steam	89.52	10.48	4.38	6.09	2.28	0	2.28	2.63	-------	1.73
Scalded 4 minutes in boiling water	90.05	9.95	4.15	5.80	2.01	0	2.01	2.52	-------	1.65
Scalded 4 minutes in boiling water and then chilled 30 seconds in cold water	90.83	9.17	3.73	5.44	1.78	0	1.78	2.33	-------	1.63
Scalded 8 minutes in boiling water	90.43	9.57	3.75	5.82	1.97	0	1 97	2.67	-------	1.64
Scalded 8 minutes in boiling water and then chilled 30 seconds in cold water	90.76	9.24	3.61	5.53	1.80	0	1.80	2.35	-------	1.48

The composition of string beans is strikingly different from that of peas. They have considerably more moisture, relatively little starch, but a much smaller total of polysaccharides than peas. Instead of cane sugar, as in peas, the sugars are all reducing sugars. Beans contain a comparatively high percentage of pentosans, which are of such a nature as to require long cooking to make the beans tender.

Comparison of the figures for the fresh green beans and those that had been scalded shows that treating with live steam causes practically no change in the chemical composition of the beans. Scalding in water alters the composition somewhat, there being an increase in moisture content and a small loss of soluble constituents. Apparently, no changes occur in the chemical composition of string beans during scalding which would not take place anyway during the subsequent processing.

Prolonged cooking gradually softens the tissues, due to the changes in the middle lamellæ and other cell structures containing pentosans. The use of sodium carbonate or other alkalis hastens this action, owing to the solvent action of the chemicals upon the pectic substances in the tissues; but, as in the case of peas, where calcium and magnesium compounds, or other of the alkaline earths, are present in appreciable quantities in the water used, the action is to harden the tissues rather than make them tender, due to the formation of insoluble pectates of the alkaline earths.

CONCLUSIONS REGARDING THE SCALDING OF STRING BEANS.

So far as appears, the chief advantages from scalding string beans before canning are the reduction in bulk and increased flexibility of the beans, which make possible a full and attractive pack, and the desirable effect produced on internal pressure and vacuum. These are so important that scalding in some form seems to be of

considerable advantage. As steam accomplishes the desired result without appreciable losses in nutrients, scalding in steam seems preferable to scalding in boiling water.

But scalding water has a cleansing action, and since the losses are relatively small the practice may perhaps have some justification. Scalding in water should not be prolonged, however, after the beans are clean and their turgidity is reduced.

As with spinach and peas, scalding does not improve the color of the canned string beans, and it is not necessary to give a clear liquor.

No advantages have been found from plunging the freshly scalded beans into cold water, and since it but adds to the labor and expense of canning it should be abandoned.

LIMA BEANS.

The work with Lima beans was limited by lack of quantity needed for extended study. Complete chemical analysis of samples of the fresh and scalded beans, and of the scalding water collected at different stages, was not undertaken, and, consequently, no tabulation of analytical data is given. Enough was done, however, to give a general idea of the relation of scalding to the quality of the canned product.

The variety used was the Improved Bush Lima. The beans were mature, but had not begun to dry, still having in them considerable chlorophyll.

The results of experiments are briefly considered below.

WEIGHTS BEFORE AND AFTER WASHING AND SCALDING LIMA BEANS.

Freshly shelled Lima beans, after washing and draining 2 minutes, showed an average gain in weight of 6.6 per cent, due largely to adhering water; but, after scalding for 4 minutes and draining 2 minutes, there was a loss of 3 per cent from the original weight. This was due to evaporation during draining, and to losses of soluble material.

LOSSES IN SCALDING LIMA BEANS.

When 4,000 grams of beans were scalded in 12,000 cubic centimeters of distilled water for 4 minutes, there was a loss of 3.3 per cent of the total dry weight of the fresh beans. The loss of solids was greater than in string beans but less than in peas. The losses in sugar and other constituents were not determined.

EFFECT OF SCALDING ON THE TASTE AND FLAVOR OF LIMA BEANS.

When the product from beans that were scalded for 4 minutes in boiling distilled water, filled into cans, hot 2 per cent brine added, and then sealed and processed at once was compared with that from beans of the same lot canned in a like manner but without preliminary scalding, it was found that when canned in tin the flavor was slightly more pronounced in the unscalded beans. With the beans packed in glass, differences in flavor were not noticeable.

EFFECT OF SCALDING ON THE COLOR AND APPEARANCE OF LIMA BEANS.

There were no perceptible differences in color between the canned product that had been scalded and that which had not been treated.

Owing to shrinkage when the beans were put into the cans without preliminary scalding, the cans were slack filled, and unattractive in this respect.

MUCILAGINOUS SUBSTANCES AND CLARITY OF LIQUOR IN CANNING LIMA BEANS.

As with peas, the seeds of Lima beans are free from mucilaginous substances when fresh. The liquor was clear, or not, depending on whether starch and protein were liberated from the beans by bursting or breaking open the testa of the seed. Handling during scalding and filling the cans caused more or less bruising and breaking of the beans; and the liquor in the cans of unscalded beans was clearer than that of the precooked. Overfilling is just as likely to cause cloudiness of the liquor as with peas, and for the same reason.

PRESSURE AND VACUUM WHEN LIMA BEANS ARE SCALDED.

What has already been said under this head in connection with peas and beans when canned in tin applies equally to Lima beans. Some form of scalding is necessary to expel air from the tissues, to reduce the pressure developed in the cans during processing, and to give the proper vacuum.

Comparative experiments with steam were not made with Lima beans, but there is no reason to suppose the results would differ from those with peas. Lima beans are similar in structure and composition to peas, and while they differ greatly in size and therefore have less surface exposed per unit of weight than peas, the results to be expected are about the same.

No experiment was made to determine the effect of plunging freshly scalded beans into cold water, but no reason occurs to the writers for expecting results different from those with the vegetables previously discussed.

CONCLUSIONS REGARDING THE SCALDING OF LIMA BEANS.

The only advantages from scalding Lima beans before canning, so far as these experiments indicate, are in the expulsion of air from the tissues, permitting a closer pack and, in the case of tin cans, reduction of internal strain on cans, and giving a better vacuum.

It is probable that steam could be used advantageously instead of boiling water, without loss of nutrients and desirable flavoring substances.

SWEET CORN.

The work with sweet corn was done with these two points specially in mind: The effects when the corn is scalded on the cob, and the results of precooking after the corn is cut from the cob without preliminary scalding.

Canning corn on the cob is done commercially by only a few concerns, and among home canners canning on the cob is not very common; but scalding before cutting the corn from the cob is quite commonly recommended, especially by writers of bulletins for home canners. Precooking the corn to 80° C. or more just before putting it into the cans is the usual practice.

In these experiments the Country Gentleman variety was used. When broken from the stalk the corn was in prime table condition.

It was gathered early in the morning and handled at once. The flavor of sweet corn deteriorates rapidly after the ear has been pulled, and for this reason it must be canned promptly if freshness of flavor is desired in the canned product.

After husking and silking, the corn was weighed, washed, and weighed again. After washing, a gain of 1.6 per cent in weight, due to adhering water, was noted. Corn on the cob, scalded for 10 minutes in boiling water, gained 2.6 per cent over the original weight, or 1 per cent over the weight just prior to scalding.

In preparing the cut corn in these experiments the outer one-third to one-half of the kernels was removed with a sharp knife and then the remainder of the edible portion was scraped from the cob.

In one lot, the corn was cut from the cob and placed in the containers without any precooking whatever. In another, after cutting from the cob, the corn was heated to 80° C. in an open enameled kettle over steam, with constant stirring, and then put into the cans and jars. A third lot was scalded on the cob in boiling water for 10 minutes, then cut from the cob and put into the containers, as before. Hot liquor—consisting of 2 per cent of common salt and 6¼ per cent of cane sugar in water—was then added to give a 4 to 1 ratio of corn to liquor, the corn and liquor were thoroughly mixed, the cans then sealed and processed intermittently for 1½ hours on three successive days.

EFFECT OF PRECOOKING ON THE QUALITY AND APPEARANCE OF CANNED CORN.

In those samples canned in glass, the flavor in all three lots was practically the same, the differences, if any, being indistinguishable. Of those canned in tin, however, that prepared without any preliminary scalding or precooking had slightly more of the fresh-corn flavor than the others. The product in each case was pleasing to the taste.

The physical character of the three lots differed somewhat. That scalded before cutting from the cob was more granular, the kernels being more or less distinct, and the corn less creamy. That cut from the cob without preliminary scalding, but precooked to 80° C. before filling the cans, was more uniform in consistency and texture, and the colloidal starchy material, formed by the gelatinization of the loose starch grains in the liquor, was evenly distributed throughout the whole. That receiving no preliminary heating, either before or after cutting from the cob, was of less uniform consistency, which made it not quite so attractive in appearance as that precooked before canning.

The physical differences in the precooked and the untreated material were much less marked when the corn was in glass jars. Escaping air during processing served to mix the material more or less, thus bringing about a somewhat better distribution of the colloidal material than there was in the tin containers, where stirring from this cause was negligible.

In studying canning problems during the last three years, the writers have done considerable work on both white and yellow varieties of sweet corn. It might appear, from discussions in the literature on the effect of scalding on the retention of natural colors, that the yellow color of corn might be affected. This has not been

found true. In no instance was the natural color better preserved in the scalded or precooked corn than in that which was untreated.

EFFECT OF PRECOOKING CORN ON PRESSURE AND VACUUM.

In the bulletin (*38*) previously mentioned, the writers showed that great internal pressures were developed in cans of corn when the corn was canned without precooking, and that the vacuum was correspondingly lower. During cooking, corn swells considerably, and unless heat is applied in some form before the corn is canned difficulties may be encountered. In tin, the cans may buckle; and when glass jars are used, breakage from internal pressure is often considerable.

This swelling is due partly to gelatinizing of the starch, but mostly to the expansion of air held in the tissues or otherwise incorporated in the material.

Scalding on the cob in boiling water has the disadvantage that more loss of sugar and other nutrients takes place, though this is not very great unless the scalding is greatly prolonged. Commercially, scalding on the cob would be impracticable, or at least expensive. The experiments of the writers have indicated that the best results are obtained when the corn, with the proper proportion of liquor, is precooked to at least 80° C., just prior to filling the cans and processing.

CHEMICAL CHANGES DURING THE PRECOOKING OF CORN.

Table 4 shows the results of chemical analyses of Country Gentleman sweet corn, before and after precooking to 80° C. The changes in composition are very slight. The slightly higher moisture content of the precooked sample is due to an error in sampling, as actually under the conditions of the precooking a slight evaporation took place. There seems to be a slight loss in sugar, but this is not enough to be of very great significance.

TABLE 4.—*Results of analyses of Country Gentleman sweet corn, before and after precooking.*

[Each result is the average of three samples.]

Treatment of material.	Average constituents (per cent).							
	Moisture.	Solids.	Alcohol.		Sugars.			Polysaccharides.
			Soluble.	Insoluble.	Reducing.	Nonreducing.	Total.	
Before precooking	69.09	30.91	7.88	23.03	1.05	3.49	4.54	19.63
After precooking to 80° C	69.57	30.43	7.40	23.03	1.01	3.03	4.04	19.89

CONCLUSIONS REGARDING THE PRECOOKING OF SWEET CORN.

These studies indicate that scalding on the cob, or precooking the cut corn, is not necessary for preservation of desirable color and flavor, but is a very advantageous means of securing a proper vacuum.

TOMATOES.

Because of its delicate structure and highly perishable nature, the preliminary treatment of the tomato preparatory to canning is a matter requiring careful attention. In no branch of canning is the exercise of good judgment more important.

Scalding, when properly done, is the best method known to facilitate the efficient and economical removal of the peel—but the scalding treatment must be under careful control or considerable losses are likely to occur and the quality of the product may be seriously affected. The need is to loosen the skin quickly and effectively, without too much softening of the pulp.

The tissues of the tomato collapse very rapidly when exposed to high temperatures, and along with this collapse goes loss of juices. Furthermore, if the scalding is too prolonged, the entire pulp softens, the tomato becomes mushy, and it is impossible to make an attractive and satisfactory pack. When scalding is properly done the skin is loosened, but the underlying pulp is not seriously affected.

In a commercial cannery, the skin is loosened by either steam or a boiling-water bath. In home canning only the latter is feasible, because scalding with steam requires an abundant supply of steam, and this under some pressure. The entire surface of the tomato must be subjected to the scalding medium instantaneously, and steaming in a boiler or colander over a kettle of boiling water, as is sometimes done with certain vegetables in the home, would heat and soften the pulp too much. If steam is used, there must be a vigorously flowing supply of it, it must be applied by means of properly arranged jets, and its application must be brief—just long enough to loosen the skin. The same applies to scalding in water. The best results can be obtained only when the water is boiling vigorously; otherwise, the tomatoes will be too much softened, and the losses will be entirely too great.

With tomatoes fully ripe but not soft, about 30 seconds' treatment with steam or boiling water is sufficient; but the person doing the scalding must be allowed a little latitude in order that the scalding may be suited to the particular tomatoes in hand. The rule should be, however, the shortest possible scalding that will sufficiently loosen the skins.

Immediately after scalding, the tomatoes should be either sprayed with cold water or plunged into a vessel or vat of clean cold water. The purpose of this is to check the softening, and to facilitate handling without waste.

Comparison of canned tomatoes peeled without scalding with others peeled after scalding and chilling in the usual way showed that these operations did not in any way improve the color or flavor of the finished product. The function of scalding and chilling in the handling of tomatoes is to make possible the economical removal of the skin.

Some form of preheating before sealing is necessary to get a good fill in the cans and jars, to prevent undue strain on tin cans during processing, and to assure good vacuum in the cans after cooling.

SWEET POTATOES.

The work with sweet potatoes was designed to determine the effects of the precooking which is usually given sweet potatoes to facilitate their peeling and packing during canning operations. Several varieties were used, including representatives of both the dry firm varieties and the soft moist types. These were grown at the Arlington Experiment Farm, near Rosslyn, Va., and the experiments were performed immediately after digging, and again after 30 days of curing and storage.[8]

The sweet potatoes were graded for size, washed, and weighed. Some were precooked for different periods in a steam chamber, and some were given similar treatment in boiling water. They were then peeled, the losses in peeling noted, and then, while still hot, packed in tin cans, sealed, and processed immediately. Samples before and after precooking were taken for chemical analysis.

Sweet potatoes were also canned without any precooking. One lot, after washing, was placed in cans without peeling, and the cans sealed and processed immediately. Another was peeled by hand before cooking, the potatoes cut into pieces 1 to 1½ inches in diameter, and put in the cans, water added to fill the interspaces, sealed, and processed immediately. A third lot, after peeling by hand, was passed through a food grinder, packed into the cans raw, and then sealed and processed as above.

The canned material prepared in the various ways was opened for careful examination for quality of the product, and chemical analyses were made to determine the effect of the preliminary treatment. The water in which the potatoes were precooked was also analyzed. The findings follow.

RELATION OF PRECOOKING TO THE PEELING OF SWEET POTATOES.

When sweet potatoes are peeled raw, whether by hand or by abrading machines, the losses are very high, amounting sometimes to as much as 30 per cent of the original weight. The loss varies with the size, shape, and variety of the potatoes. The greatest loss is with small and irregular-shaped roots, and the smallest with large smooth ones. In some of these tests, using potatoes 2 to 2½ inches in diameter, there was an average loss of 22.8 per cent when the potatoes were peeled by hand. With machine peeling, the losses average about the same.[9] Although some of this loss is of inedible material, considerable valuable food is lost in this way, for it is not possible to remove the peel economically without removing considerable of the edible part with it.

When sweet potatoes are peeled after preliminary cooking, either in steam or in boiling water, the losses are much less. In these experiments, the loss in peeling after steaming for 30 minutes amounted to only 13.2 per cent, and the figures were about the same (13.8 per cent) when the precooking was in boiling water for the same length of time.

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[8] The potatoes were cured for 10 days, at a temperature of 85° F. and then stored at 55° to 65° F. for 20 days longer.

[9] Dr. J. S. Caldwell, Office of Horticultural Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, in a personal communication, reports for 12 varieties of sweet potatoes of all sizes losses ranging between 22 and 25 per cent. With lye peeling, the losses were from 2 to 2½ per cent less.

In cooking, the outer portion of the cortex separates from the deeper lying tissues, and the peel ordinarily may be removed readily by hand. The ease of peeling varies somewhat with different varieties. Usually the soft, moist types peel most readily.

The length of the treatment for most satisfactory results varies with the size of the sweet potatoes. Peeling may be done easily before the potatoes are completely cooked; but, for other reasons, it is desirable that the heat penetrate to the center of the potatoes before they are removed for peeling. Treatment in flowing steam for 30 to 35 minutes for sweet potatoes 2 to 3 inches in diameter has been found satisfactory.

LOSSES OF DISSOLVED SUBSTANCES IN PRECOOKING SWEET POTATOES.

When sweet potatoes are precooked in boiling water there is some loss due to substances going into solution in the water, but this loss is too small to be of practical importance. With potatoes 2 to 2½ inches in diameter when cooked in boiling distilled water for 30 minutes, there was a loss of 0.33 per cent of the total dry matter. Examination of the water did not show the iodine reaction for starch, and the tests for sugars showed exceedingly small amounts.

Gore (*31*), in experiments on the amount of substances going into solution during scalding and cooking in boiling water, found in the water after 3 minutes of cooking 0.17 per cent of the total solids of the sweet potatoes; after a second treatment of the same duration, 0.16 per cent; and after a third treatment, 0.12 per cent. The water in which the same potatoes were boiled for 1 hour and 20 minutes longer was found to contain 2.14 per cent of the total solids of the potatoes. In the same paper, this worker reported a loss of 0.33 per cent of the total solids, when sweet potatoes that had been washed and trimmed were steamed for 1 hour and 20 minutes.

It is seen, therefore, that even when precooked in boiling water, the losses from sweet potatoes are small, when the skins are left on.

RELATION OF PRECOOKING TO QUALITY AND CLOSENESS OF PACK OF SWEET POTATOES.

In a report of studies of the canning quality of different sweet-potato varieties, the writers (*39*) have shown that a close pack is very essential. Unless the material is packed very closely in the can, darkening and discoloration of the canned product occurs. When whole raw potatoes are packed into the cans, only 50 or 60 per cent as much material can be put in the can as may be done when the potatoes are cooked. This means that there is a very considerable amount of air in the cans. Under these conditions it is practically impossible to prevent discoloration of the product.

When the raw sweet potatoes are passed through a food grinder, and then placed in the cans, underfilling may be avoided, but the appearance of the finished product is not attractive. Also, the texture is granular. When canned in tin, too great strains are likewise developed during the processing.

Cooking and filling into the cans while still hot gives a closer pack, removes most of the air, and thus helps to make a satisfactory vacuum—essentials for best quality in canned sweet potatoes.

During preliminary cooking, a pronounced intensification of the color occurs in the sweet potatoes. This is due, in part at least, to

driving air out of the tissues, and gelatinization of the starch, which results in a more transparent condition. Exactly what changes, if any, are brought about in the carotinoids, or other pigments, is not known.

EFFECT OF PRECOOKING ON THE TASTE AND FLAVOR OF SWEET POTATOES.

Sweet potatoes precooked in water and in steam showed no perceptible differences in flavor. Those canned whole in tin without precooking sometimes developed an undesirable taste due to interaction of the metals and air on the canned material. The product from the potatoes canned raw, after passing through the food grinder, was likewise inferior in flavor to that canned after precooking.

CHEMICAL CHANGES IN SWEET POTATOES DURING PRECOOKING.

In Table 5 are shown results of chemical analyses of the varieties of sweet potatoes sampled both before and after precooking for 35 minutes in the steam chamber. The Nancy Hall represents the soft moist varieties, and the Big-Stem Jersey the firm dry varieties. Both were analyzed immediately after digging, and again after 30 days' curing and storage.[10]

In the publication already mentioned (*39*), the writers pointed out that the firmness or softness of the different varieties depends on the nature of the polysaccharide content. In the moist soft varieties, there is a high dextrin content and a somewhat larger amount of sugar than in the dry firm group. Owing to the difficulty of making complete separations of starch, dextrin, and sugars, the writers pointed out that the figures given for dextrin were probably much too low. It is shown in these pages that it is during the cooking that the starch is changed to dextrin, sugar, and other intermediate products.

The samples for chemical analysis in the present experiments were prepared by passing about 2 kilograms of the precooked material through a food grinder, mixing thoroughly, and weighing a quantity into a large beaker. Enough 95 per cent alcohol was then added in quantity to make 80 per cent strength. The raw samples were heated in the alcohol to about 70° C., to stop enzyme action. After standing over night, the alcohol was decanted through an extraction thimble, and more 95 per cent alcohol added to the material. After thorough stirring, this alcohol was decanted through the extraction thimble, and the operation repeated four or five times. The residue was then transferred to the extraction thimble, and extracted in a Soxhlet apparatus, to remove the last traces of soluble substance.

Sugars were determined by the copper-reduction method recommended by the Association of Official Agricultural Chemists (*3*). Determinations also were made on the alcoholic extract, both before and after inversion, as for cane sugar, and also after inversion with diastase.

An attempt was made to determine dextrin, soluble starch, and insoluble starch in the residue after alcoholic extraction. The carefully dried residue was ground to a very fine powder, and a weighed quantity extracted with water at room temperature. This was filtered through a Gooch crucible with asbestos mat, the residue

[10] See footnote, p. 28.

washed repeatedly, and the filtrate finally made up to volume. The carbohydrates were then determined by inversion with hydrochloric acid.

TABLE 5.—*Results of chemical analyses of Nancy Hall and Big-Stem Jersey sweet potatoes, before and after cooking for 35 minutes in steam, sampled immediately after digging and after curing and storage for 30 days.*

[*Explanation.*—In first column: Extract=alcoholic extract; residue=residue after extraction.]

Variety and treatment.	Constituents (per cent).									
	Moisture.	Solids.	Reducing sugars.			Dextrin.	Starch.		Polysaccharides, as starch.	Carbohydrates.
			As invert.	Increase after—			Soluble.	Insoluble in cold water.		
				Acid inversion as for cane sugar.	Action of diastase.					
NANCY HALL.										
Immediately after digging:										
Uncooked—										
Extract		3.84	0.20	2.16	0					2.36
Residue		25.76				0	0	21.28	21.28	21.28
Total	70.40	29.60	.20	2.16	0	0	0	21.28	21.28	23.64
Cooked—										
Extract		14.87	5.84	2.35	4.49					12.68
Residue		13.52				.21	1.03	8.98	10.21	10.21
Total	71.61	28.39	5.84	2.35	4.49	.21	1.03	8.98	10.21	22.89
After curing and storage for 30 days:										
Uncooked—										
Extract		6.16	.46	4.06	0					4.52
Residue		26.12				0	0	22.31	22.31	22.31
Total	67.72	32.28	.46	4.06	0	0	0	22.31	22.31	26.83
Cooked—										
Extract		21.86	8.97	4.80	4.55					18.32
Residue		11.97				6.15	.99	1.63	8.77	8.77
Total	66.17	33.83	8.97	4.80	4.55	6.15	.99	1.63	8.77	27.09
BIG-STEM JERSEY.										
Immediately after digging:										
Uncooked—										
Extract		3.58	.13	1.73	0					1.86
Residue		27.35				0	0	22.54	22.54	22.54
Total	69.07	30.93	.13	1.73	0	0	0	22.54	22.54	24.40
Cooked—										
Extract		14.65	6.63	1.92	3.26					11.81
Residue		16.06				.97	11.49	12.46	12.46	
Total	69.29	30.71	6.63	1.92	3.26	.97	11.49	12.46	24.27	
After curing and storage for 30 days:										
Uncooked—										
Extract		6.14	.88	3.26	0					4.14
Residue		27.25				0	0	22.50	22.50	22.50
Total	66.61	33.39	.88	3.26	0	0	0	22.50	22.50	26.64
Cooked—										
Extract		18.80	7.78	3.33	4.27					15.40
Residue		15.83				.33	.92	10.49	11.74	11.74
Total	65.37	34.63	7.78	3.33	4.27	.33	.92	10.49	11.74	27.14

Another portion of the residue was extracted in the same way and the filtrate treated with basic lead acetate to precipitate the starch. This was then filtered through a dry asbestos mat, and an aliquot portion, after removal of the lead, inverted with hydrochloric acid in the usual way.

The portion soluble in water and not precipitated by basic lead acetate is designated in the table as dextrin, and the portion soluble in water but precipitated by basic lead acetate is designated as soluble starch.

It must be remembered that these figures are but rough indications of the actual quantity of these substances present, for it is hardly possible that a complete separation of the various constituents can be made in this way. However, the samples were all handled in the same manner and the figures are, therefore, entirely comparable.

A glance at the table shows that very great changes occur during the precooking. Three to four times as much material was extracted by the alcohol from the cooked as from the uncooked potatoes. During precooking, large quantities of starch are changed to reducing sugar, probably maltose, and other intermediate products. Dextrose, cane sugar, probably maltose, and substances closely related to dextrin are found in the alcoholic extract, while the residue contains starch, dextrin, and intermediate products.

The increase in sugars in the alcoholic extract, after inversion with diastase, would seem to indicate the presence of polysaccharides. However, a blue color is not given by iodine, but a slightly reddish color instead. This increase probably is due to inversion of maltose.

There is no difference in the reducing power after the acid inversion and after the action of diastase in the extract of the raw sample, but in the extract of the cooked sample the difference amounts to 3 to 4.5 per cent.

The amount of reducing sugars in the raw sample is unusually low, less than 1 per cent. Ordinarily, the reducing sugars amount to about 2 per cent in the fresh, raw, sweet potato.

During precooking, the percentage of reducing sugars increases very greatly, amounting to as much as 8.9 per cent in some cases.

The figures indicate very little change in the cane sugar. The difference in results before inversion and after inversion is a little greater in the cooked than in the uncooked sample. This is probably due, however, to the influence of intermediate sugars rather than to increase in cane sugar.

The change in sugar content during cooking is greater after storage than when the cooking is done immediately after digging. Some transformation evidently occurs during storage which, upon cooking, results in a marked change of starch into sugar.

Gore (*30*) has shown that the sweet potato contains a considerable amount of diastase and that, with a very slow cooking of it in water, very nearly all the carbohydrates are changed to a soluble form. He has applied this fact in the manufacture of sweet-potato sirup. When the potato is cooked rapidly, the action of this diastase is apparently much less complete. The amount of change that occurs with rapid cooking differs with the variety of sweet potato used and

varies greatly with the time after digging when the cooking is done. This would seem to indicate that there is an increase in amount of diastase during storage. No determinations, however, were made on this point.

The residues, after extraction with alcohol, contain various proportions of starch, dextrin, and intermediate products. In the uncooked Nancy Hall variety the amount of dextrin was found to be negligible. When cooked immediately after digging, a dextrin content of 0.21 per cent was found, and after storage the cooked potatoes showed 6.15 per cent. In the Big-Stem Jersey only small amounts of dextrin were found in the cooked potatoes, both immediately after digging and after curing and storage. Where a large amount of dextrin was found, the potatoes were soft and "moist"; while in the varieties which remained firm after cooking, very little dextrin was found, but the polysaccharide was largely starch.

It is apparent, therefore, that differences in sweetness and firmness of cooked sweet potatoes are due largely to the changes that occur during the cooking process.

MICROSCOPIC APPEARANCE OF PRECOOKED SWEET POTATOES.

Examining the cooked material under the microscope shows the cells to be more or less distorted in shape, and partly or entirely separated from each other. Very few broken or burst cells are seen. The heat seems to soften the pectic substances of the middle lamellæ, or cause them to dissolve, so that the cells which they ordinarily hold together are allowed to separate. Differences in the amount and rate of this change may account to some extent for the differences in the cooking quality of the various kinds of sweet potatoes.

CONCLUSIONS REGARDING THE PRECOOKING OF SWEET POTATOES.

Precooking of sweet potatoes, for a longer or shorter time, in either live steam or boiling water, is of great advantage when they are to be canned. It facilitates peeling and proper packing. By packing hot, the air is more completely eliminated from the can than can be accomplished in the ordinary exhaust, and discoloration of the product is reduced to a minimum.

During the precooking, very significant chemical changes occur in the carbohydrates of the sweet potatoes. A large amount of starch is converted into sugar, dextrin, and intermediate products. The amount of the change and the character of the constituents formed vary with the conditions of storage, and with the variety of potatoes.

In those cases where a very soft product is obtained, the starch is largely changed to sugar and dextrin; while with the varieties that yield a firm product after cooking, little dextrin is formed, and considerable amounts of starch remain unhydrolyzed.

GENERAL DISCUSSION.

In the presentation of the matter in hand, it is thoroughly recognized that considerations of very great importance, in connection with studies upon scalding and precooking, have not been

touched upon in the present experimental work. The relation of scalding to the keeping quality of the canned foods is one of these.

RELATION OF SCALDING TO KEEPING QUALITY.

The impression prevails with many that scalding has a direct, favorable bearing upon the keeping quality of canned foods, and that the process in itself has great value from a bacteriological standpoint. The matter warrants the most careful consideration, and it is proposed to investigate this point.

To favorably affect the keeping quality of foods, and justify any modification in the severity of processing operations, scalding must do certain things: (1) Facilitate heat penetration, and (2) bring about an actual destruction of the microorganisms which cause spoilage or reduce their resistance to heat.

That preliminary scalding assists in cleansing the food materials, and may wash away many of the bacteria with which they are contaminated, is too well known to require discussion, but this reduction in contamination does not mean that the processing temperatures or time periods can be reduced.

It is conceivable that occasionally raw material might be cleansed of all spore-formed bacteria by scalding in boiling water, and thus the subsequent processing might be reduced in severity, but there is no way at present of knowing when this condition has been attained; and for the sake of safety in food preservation, the reduction of the processing temperature and time periods must be looked upon as a matter too risky to be considered seriously.

A fact commonly overlooked is that the water of the scalding bath may actually contaminate the raw materials being treated in it by transmitting to them the spores of microorganisms derived from material previously scalded in the same water. This may occur especially when the same water is used repeatedly. To what extent contamination of this kind takes place in actual practice is unknown, but the possibilities of its occurrence decrease more and more as sanitary measures are observed. It presents another reason, however, why in the scalding process clean fresh water must be used.

The influence which scalding as a preliminary canning operation has upon the destruction of microorganisms calls for careful consideration.

That a brief treatment in boiling water is of great value in destroying the vegetative forms of many bacteria and other microorganisms is unquestioned. But it is not so much with these that the real problems of food preservation are concerned. Were it not for the fact that many of the bacteria responsible for spoilage in canned foods form spores which are very resistant to heat, the preservation of foods would be relatively simple. Processing operations must be directed, therefore, to the destruction of these highly resistant forms.

No attempt has been made to bring together all the literature bearing upon this particular phase of the subject, and reference will be made to the reports of but a few investigators. Globig (*29*) reported studies on a potato bacillus killed in streaming steam at 100° C., only after 5 to 6½ hours' exposure. Christen (*23*) described an

organism which survived 4 hours at 100° C., and mentioned others that withstood this temperature for 8 hours and 16 hours, respectively. Burke (*20*), in researches on the resistance of the spores of *Bacillus botulinus*, the organism responsible for much sickness and many deaths through eating food poisoned by it, reported that the temperature of 100° C. inhibited the development of the spores, so that the incubation period greatly lengthened, but found that 4 hours of boiling was not sufficient to kill the spores from hardy strains of this organism. Bigelow and Esty (*8*), in studies on a considerable number of thermophilic bacteria isolated from spoiled canned food, found that some of these were still alive and able to develop after exposure, in corn juice, to the temperature of 100° C. for 19 to 20 hours. Their resistance to temperature was found to vary when heated in the juices of other vegetables, but in none were they completely destroyed in the time required for efficient preliminary scalding of the vegetables. No retardation in germination of spores of these thermophiles as a result of exposure to high temperature was observed.

These findings of different investigators show conclusively that the treatment which the spores of bacteria receive during preliminary scalding can not be relied upon to destroy them or materially weaken their vitality.

Within recent years, the notion became prevalent that sudden change from high to low temperature decreased the resistance of bacterial spores to subsequent heating, and out of this belief was developed the practice in home canning of plunging freshly scalded vegetables into cold water just before putting into the cans. The assertion of the germicidal effect of sudden changes of temperature, however, led to careful studies by different workers in various parts of the country, and the findings of some of these are presented herewith, as they have a direct bearing on the subject in hand.

Ayers and Johnson (*4*), working in the Government laboratories in 1913, reported the results of studies on the bacteria which survived pasteurization of milk. These investigators found that milk pasteurized at 62.8° C. (145° F.) for 30 minutes, and then cooled in 15 seconds to 1.7° to 3.9° C. (35° to 39° F.), showed as many viable bacteria after the chilling as in milk pasteurized for 30 minutes at 71.1° C. (160° F.) and then chilled as before; and, from these experiments, they concluded that sudden cooling was of no value in causing destruction of bacteria, at least within the range of temperatures then used. Bushnell (*21*), in a long series of experiments on the sterilization of canned foods, showed that the thermal death point of pure cultures of bacteria was not affected by the treatment; that the length of the scalding period (5 to 20 minutes), or the rapidity of cooling, did not in any way influence the ease with which the spores were subsequently killed by heat; that spores of bacteria were not devitalized by chilling; and that scalding for rather long periods followed by plunging into cold water did not aid in sterilization of canned foods.

Buchanan and his collaborators (*19*)—in a preliminary report of experiments with the *Bacillus pseudotetani* in spore form, to determine the effect of scalding and chilling by calculating the velocity coefficient of the death rate of bacteria that had been heated and chilled with a similar coefficient of unchilled bacteria at temperatures

of 80°, 90°, and 100° C.—could find no significant differences. In a further report on these same studies, Bruett (*18*) expressed the conclusion that bacterial spores, apparently, are not made sensitive to heat by a preliminary heating that is followed by chilling; and that the sudden cooling does not cause the bacteria to succumb more readily to the sterilization process.

The writers, during the several years these studies have been carried on, have observed as much spoilage in cans that were given the combined preliminary heating and chilling as in those where there had been scalding only. In the face of the evidence, therefore, they come to the conclusion that chilling in cold water immediately after scalding serves no useful purpose from the standpoint of ease in sterilizing canned foods.

There remains to be considered in this connection the relation of scalding or precooking to heat penetration. Two phases of this matter present themselves: The relation of scalding to the rate of convection which takes place in the liquid of the can, and the relation of scalding or precooking to initial temperatures.

In a previously mentioned bulletin (*37*) the writers showed that any influence which affects the fineness of division and compactness of the material, and the amount and viscosity of the free liquid, affects the rate of temperature change in the material in the can. In some cases scalding does not bring about material alterations in the rate of the convection currents in the can, and in such cases is not important; but in some instances scalding increases the viscosity of the liquid and, because of the slowing down of the convection currents, delays complete sterilization. In another bulletin, also previously mentioned, the writers (*38*) showed how differences in initial temperatures affect the time-temperature curves during canning operations, higher initial temperatures allowing of possible shortening of processing periods, and lower initial temperatures making more processing necessary to get the same degree of temperature at the center of the can. Scalding, when followed immediately by processing, therefore, may shorten the processing period; and chilling, when this is practiced, makes more prolonged processing necessary.

The practical application of these facts should be clear to all.

ECONOMIC CONSIDERATIONS.

The modern housewife demands canning methods that are simple and time saving. Unnecessary steps must be eliminated. In the case of the commercial plant, success or failure of the enterprise depends on the time and labor necessary for the production of the finished product. Scalding, precooking, and chilling are costly operations—costly in time, labor, fuel, and, sometimes, food material. Careful thought, therefore, must be given to this matter, and practices must be justified by considerations of economy before they are adopted.

Experimental work has shown that with several vegetables—such as peas, Lima beans, and string beans, especially when packed in glass—the differences in quality between the scalded and unscalded products were too small to be significant. In other cases, as with spinach canned in tin, the quality was favorably affected by scalding. The main advantages of scalding, in most cases, seemed to be the

full pack which the increase in flexibility made possible, and the lessened strain on cans.

To reduce strain on cans, and get the proper vacuum, a separate operation, known as exhausting, is generally practiced. Exhausting, ordinarily, is done by heating the cans for a short time just before sealing. Scalding and exhausting are, therefore, the same in principle; one consists of heating material before putting it into the can, and the other of heating after it is put into the can. The vacuum obtained depends on the temperature of the material at the time of sealing. When the scalded material is filled into the cans while hot and sealed immediately exhausting may not be necessary. With some food substances scalding may be unnecessary, if the exhausting is done. In many cases, if not most, one operation or the other may be eliminated with a saving of time and cost.

Plunging freshly scalded material into cold water, because of the lowering of the temperature, makes an exhaust necessary, which increases the labor cost of canning. There are times, as in the peeling of tomatoes, when this practice is justified, but the general application of it to all canned materials seems unwarranted to the writers.

GENERAL SUMMARY.

In the preparation of fresh vegetables for canning, a preliminary scalding, in most cases, results in a greater or less reduction in bulk, due to loss of turgidity of the tissues and the expulsion of air. This reduction may amount to as much as 50 to 60 per cent, as in the case of spinach, or to as little as 6 to 15 per cent in the case of peas. In general, this shrinkage permits a closer and more attractive pack. If care is not exercised, however, it may lead to overfilling, as with mature peas and lima beans, which swell during the subsequent processing.

The expulsion of air from the tissues by scalding reduces the internal strain on tin cans during processing and permits a higher vacuum.

When scalding is done in boiling water, there are losses of soluble food materials. These may amount to as much as 16 to 30 per cent of the total dry matter, as in the case of spinach, or as little as $1\frac{1}{2}$ to 10 per cent in the case of string beans. When the scalding is done in steam, very little of such loss takes place, unless the water of condensation is allowed to drip through the material.

Neither scalding alone, nor scalding followed by chilling in cold water, results in a more complete retention in the finished product of the natural colors of the fresh vegetables than is obtained when there is no preliminary scalding. Since scalding helps to eliminate air from the material, it may reduce the amount of discoloration due to oxidation which takes place in canned goods.

Scalding has very little effect on the flavor and taste of vegetables packed in glass jars. If the scalding is in water, the product may not be as sweet as that not scalded. When canned in tin, the unscalded product retains more of the natural flavor than that which has been scalded. This may be objectionable with some vegetables, such as spinach, but in most cases, in the opinion of the writers, the unscalded product is superior in flavor.

Certain chemical changes occur during scalding and precooking which, with some vegetables, are very important. In most cases, the protein is altered somewhat, and the starch partially gelatinized. No significant changes occur in the sugars. With the sweet potato, however, marked transformations take place, in which much of the starch is converted into sugars, dextrin, and intermediate products, and the degree and character of these changes are responsible for the difference in consistency and in sweetness of the canned product.

In the preparation of such materials as tomatoes and sweet potatoes, scalding is an efficient method of loosening the skin, so that peeling is easily accomplished. In the case of tomatoes, spraying with cold water, or chilling promptly after scalding, is advantageous in hardening the pulp and thus making the fruit easier to handle.

During scalding and the subsequent processing, the cells of the vegetable tissues tend to separate from each other, and the material becomes softened. This is due to the softening and partial dissolving of the pectic substances of the middle lamellæ which hold the cells together. Ammonia and the hydroxides of the alkali metals hasten this action, because the pectic materials are more soluble in these reagents. The alkaline earths, on the other hand, form insoluble compounds with the pectic substances, and the tissues are hardened rather than rendered more tender. For this reason, hard water used either in the scalding bath or in the liquor causes a hardening of the tissues and detracts from tenderness.

When freshly scalded or precooked materials are packed immediately, the exhaust may be unnecessary. On the other hand, many of the advantages of scalding may be afforded by a good exhaust.

Scalding, or scalding followed by chilling, does not reduce the time necessary for successful processing. Scalding assists in cleansing the raw materials when fresh, clean water is used, but may have the opposite effect when the scalding water is used repeatedly.

From the standpoint of expense of canning, scalding and chilling should be avoided wherever possible, and, in choosing a procedure, care should be taken to make it simple and economical of time and labor.

Chilling in cold water following scalding has no appreciable beneficial effect on the quality, flavor, or appearance of the finished product. It results in further losses of food material, makes subsequent exhaust necessary, and is therefore an expensive operation. The work of different investigators indicates that it has no justification from a bacteriological standpoint. The only value of chilling, so far as these investigations have indicated, is temporary hardening of the pulp of certain fruits and vegetables which must be peeled by hand.

Some form of scalding is desirable in the preparation of most vegetables, especially when they are to be canned in tin. Live steam, if available, is preferable to boiling water, since it produces all the desirable effects of scalding without causing appreciable losses of nutrient materials.

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A LIST OF PERTINENT NONTECHNICAL LITERATURE.

As pointed out in the introductory portion of this bulletin, present-day canning technology has been determined in large measure by the recommendations from a voluminous semiscientific or nontechnical literature. For the benefit of those investigators who may need to look into the matter in greater detail than has been possible in the present case, a list of the more important of these pertinent papers is given below. With the exception of a few widely read texts, the list is made up almost exclusively from the official publications of Federal and State canning specialists. Similar papers, which merely quote from other writings, or whose authors assume no responsibility for the recommendations given, are omitted.

ANONYMOUS.

1914. A complete course in canning. Ed. 3. 240 p., 3 fig. [Baltimore].

1915. Canning. U. S. Dept. Agr., Bur. Plant Indus., Farmers' Cooperative Demon. Work, no. 631, revised, 6 p.

1917. Canning fruits and vegetables. Wis. Univ. Agr. Ext. Serv. Circ. 88, 6 p.

1917. Food preservation; a national challenge. N. Y. State Col. Agr. Cornell Reading Course. Food Ser. Lesson 113, p. 133–184, fig. 51–62.

1917. Home canning. Vt. Agr. Col. Ext. Serv. Circ. 6, 16 p., illus.

1917. The one-period cold-pack method of canning. Brooklyn Bot. Gard. Leaflets, ser. 5, no. 9, 4 p.

1918. Instructions for canning and preserving. Maine Univ. Agr. Ext. Bul. 112, revised, 24 p., illus.

1918–19. Preservation of food. Ohio Univ. Agr. Col. Ext. Serv. Bul., v. 14, no. 1, 20 p., 2 fig. References, p. 20.

1919. A complete course in canning. . . Ed. 4, 254 p., illus. Baltimore.

1920. Food preservation. N. Y. State Col. Agr., Cornell Reading Course. Food Ser. Lesson 136, p. 93–176, fig. 36–45. References, p. 173.

1921. Home canning of fruits and vegetables. Conn. Agr. Col., Ext. Serv. Bul. 40, 10 p.

1921. Home canning of fruits and vegetables. U. S. Dept. Agr., Farmers' Bul. 1211, 51 p., 15 fig.

ADAMS, L. H., and SANDSTEN, E. P.

1906. Practical directions for preserving native fruits and vegetables. Wis. Agr. Exp. Sta. Bul. 136, 13 p., illus.

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1918. Home canning, drying and preserving. xvi, 150 p., port., 15 pl. Garden City, N. Y.

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1916. Canning in glass by the cold pack method. Mo. Univ. Col. Agr., Ext. Serv. Circ. 9, 12 p., 6 fig.

BELT, SARAH ELIZABETH.
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BENSON, O. H.
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1915. Home canning club instructions to save fruit and vegetable waste. U. S. Dept. Agr., Off. Farmers' Cooperative Demonstration, N. and W. States, 4 p.

1917. Classification of fruits and vegetables for club canning. U. S. Dept. Agr., S. R. S. Doc. 17. Ext. N. NR–24, 6 p.

1917. Home canning by the one-period cold-pack method. U. S. Dept. Agr., Farmers' Bul. 839, 39 p., 24 fig. Reprinted, 1918.

1920. Home canning and food thrift. N. Y. Dept. Farms and Markets. Div. Agr. Bul. 130, 61 p.

BREAZEALE, J. F.
1909. Canning vegetables in the home. U. S. Dept. Agr., Farmers' Bul. 359, 16 p., 9 fig.

BUTZ, GEORGE C.
1902. Canning of fruits and vegetables. Pa. State Dept. Agr., Bul. 91. 57 p., illus.

CALVIN, HENRIETTA W., and LYFORD, CARRIE A.
1918. The preparation and preservation of vegetables. U. S. Bur. Ed., Bul. 47, 24 p.

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CRUESS, WILLIAM V.
1917. Home and farm canning. Calif. Agr. Exp. Sta. Circ. 158, 32 p., 10 fig.

1917. Canning fruits and vegetables. Methods of food preservation, I. Calif. Agr. Exp. Sta. Leaflet, 4 p., illus.

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1921. Perforation and corrosion of tin plate. *In* The Canner, v. 53, no. 25, p. 27–28.

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ELLIOT, H. S.
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1919. Every step in canning. vii, 253 p. Chicago.

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1919. Cold pack method for home canning. Purdue Univ., Dept. Agr. Ext. Bul. 82, 8 p., 3 fig.

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HAYES, MAUD E.
1919. A canning catechism to supplement State and Government information. Conn. Agr. Col., Ext. Serv. Bul. 12, 8 p.

HICKMAN, ALICE S., et al.
1917. Home demonstration work as correlated with the Louisiana public schools. La. Univ., Agr. and Mech. Col., Ext. Bul. 24, 170 p., illus.

HILL, JANET MCKENZIE.
1915. Canning, preserving, and jelly-making. ix, 189 p., 8 pl. Boston.

HOGENSON, J. C.
1914. Home canning of fruits and vegetables. Utah Agr. Col., Ext. Div. Circ., v. 2, no. 25, 10 p.

HUGHES, MARY B.
1918. Everywoman's canning book. viii, 96 p., illus. Boston

JOHNSON, MARGARET M.
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1917. Home canning by the cold pack process. Purdue Univ., Dept. Agr. Ext. Bul. 55, 8 p., 3 fig.

1918. Home canning one period, cold pack method. S. Dak. Col. Agr., Ext. Circ. 4, 8 p.

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